HYPERVELOCITY IMPACT RESPONSE OF SPACED COMPOSITE MATERIAL STRUCTURES

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All large spacecraft with a mission duration of more than a few days are susceptible to impacts by meteoroids and pieces of orbiting space debris. These impacts occur at extremely high speeds and can damage the flight-critical systems of a spacecraft. This damage can in turn lead to catastrophic failure of the spacecraft. Therefore, the design of a spacecraft for a long-duration mission must take into account the possibility of such impacts and their effects on the spacecraft structure and on all of its exposed subsystem components, such as instrumentation units and solar arrays.

Structural walls for crew compartments and spacecraft modules have traditionally consisted of a bumper plate that is placed at a small distance away from the main pressure wall of the compartment or module. This concept was first proposed by Whipple [1] and has been studied extensively in the last two decades by this author and other investigators as a means of reducing the penetration threat of hypervelocity projectiles (see, e.g. [2-9]). However, in the majority of these investigations, the bumper and structural wall were typically made from high-strength metallic materials, such as aluminum or steel. With the advent of many new high-strength composite materials and their proliferation in aircraft applications, it has become necessary to evaluate their potential for use in long-durat n space and aerospace structural systems. One aspect of this luation is the analysis of the response of composite structural systems

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to hypervelocity impact loadings. Unfortunately, information on hypervelocity impact of composite materials is scarce because work in this area has just begun [10]. Only recently, Yew and Kendrick presented a description of the various types of damage that was produced in graphite fiber composite panels by the hypervelocity impact of a simulated space debris particle [11].

This paper presents the results of an investigation into the response of dual-wall composite structural systems under hypervelocity projectile impact loadings. In the first section, a review of the experimental procedure used in the hypervelocity impact testing of spaced composite material targets is presented. The materials considered in this study were Kevlar and graphite/epoxy. A schematic diagram of a typical test fixture is presented in Figure 1. In the next section, impact test results are reviewed qualitatively. Impact damage is characterized according to ejecta type, extent of delamination, penetration, surface damage, and spall damage in the bumper and structural wall plates. In the following sections, the test data obtained are reduced and analyzed. The analysis indicates that the extent of the damage to the bumper and pressure wall plates can be written as functions of the impact parameters of the original projectile and the geometric and material properties of the projectile/dual-wall specimen system. These functions can be used to perform parameter sensitivity studies and to evaluate hypothetical design configurations. The damage in the impacted composite material specimens is also compared to the damage in similar aluminum specimens. An equivalence analysis is performed by comparing resulting impact damage in corresponding composite and aluminum dual-wall systems. This equivalence

analysis, together with the overall composite material impact response analysis performed in earlier sections, is used to determine the advantages and disadvantages of employing composite materials in the design of structural walls for long-duration spacecraft. In the final section, conclusions are made based on the results of this investigation. Several recommendations for future research activities in the hypervelocity impact testing of composite materials are also presented.

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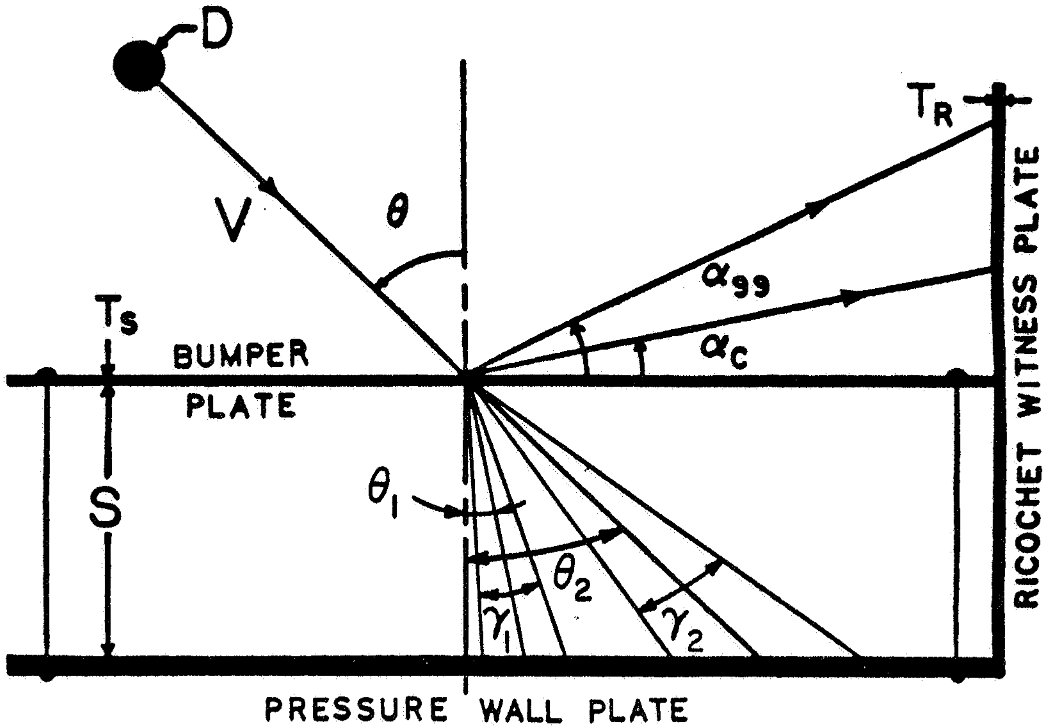

Figure 1 -- Dual-Wall Specimen Configuration